3D Moving Mesh Simulations of Galactic Center Cloud G2

P. Chris Fragile[1], Peter Anninos[2], and Stephen D. Murray[2]

[1]Department of Physics & Astronomy, College of Charleston, Charleston, SC: fragilep@cofc.edu;

[2]Lawrence Livermore National Laboratory, Livermore, CA 94550

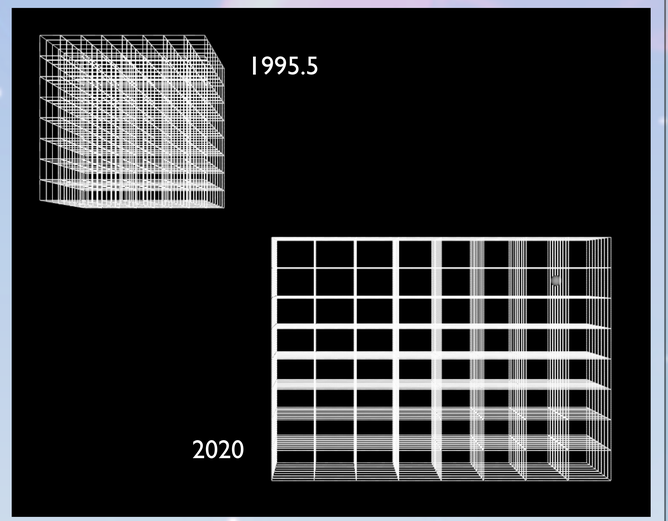
Using three-dimensional, moving-mesh simulations, we investigate the future evolution of the recently discovered gas cloud G2 traveling through the galactic center. From our simulations we expect an average feeding rate in the range of (5–19) × 10^{-8} $M_\odot$ yr^{-1} beginning in 2014. The accretion varies by less than a factor of three on timescales ~1 month, and shows no more than a factor of 10 difference between the maximum and minimum observed rates within any given model. These rates are comparable to the current estimated accretion rate in the immediate vicinity of Sgr A*, although they represent only a small (<10%) increase over the current expected feeding rate at the effective inner boundary of our simulations (r_{acc} = 750 R_S ~ 10^{15} cm). We also produce Br-γ images and light curves from our simulation data, which can be compared directly with observations. Because of tidal compression normal to the orbital plane, all of our isothermal models predict significant (factor of 10) enhancements in the Br-γ luminosity of G2 as it approaches pericenter, in conflict with observations. This puzzle suggests there must be some inconsistency in the assumptions made in our simulations.

Simulations

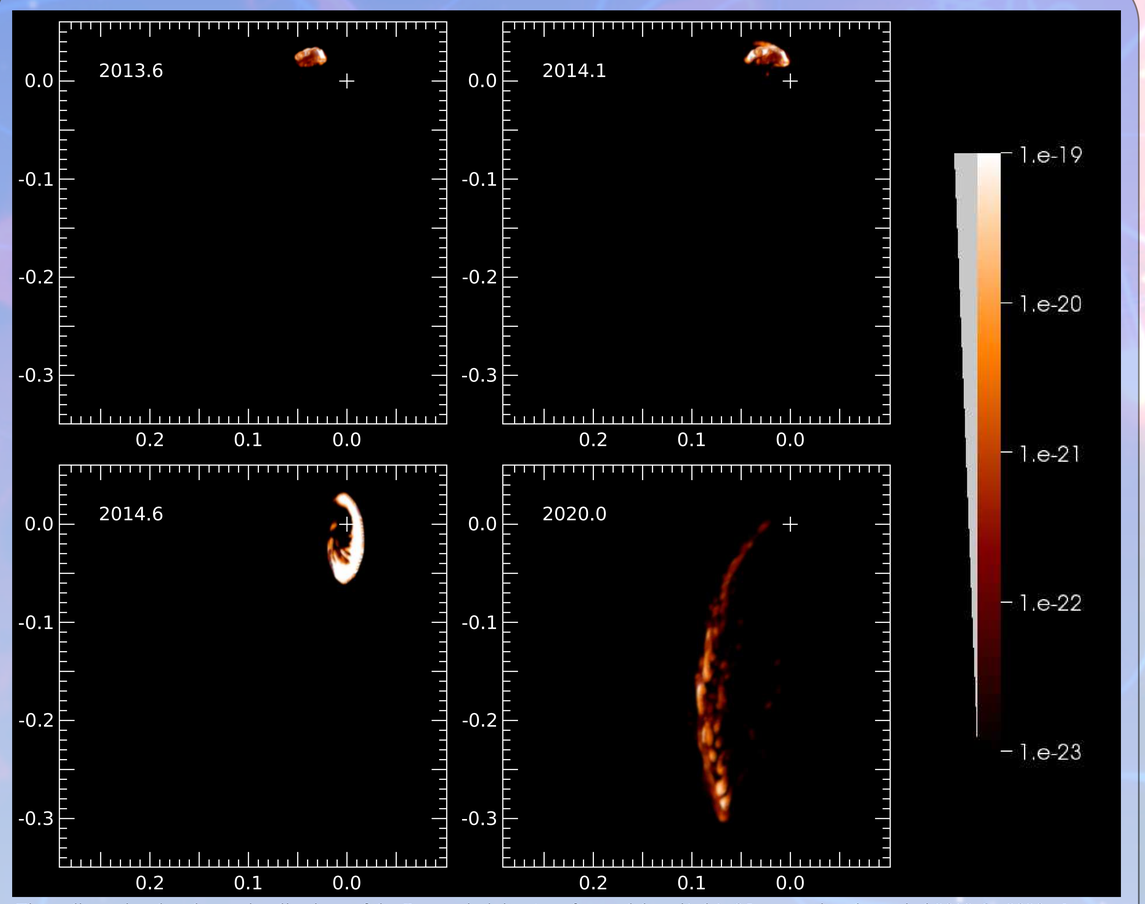
Using the moving mesh that we introduced in [1], we simulate the evolution of a gas cloud on the orbit of G2 through the galactic center. Each simulation uses a Cartesian grid with a starting size of 14 R_c, resolved with 256 zones in each dimension, giving an initial linear resolution of $\Delta x, y, z = 8.2 \times 10^{13}$ cm. We fix the motion of the mesh using the Keplerian velocity of the cloud. We experiment with three different equations of state: isothermal, isentropic, and polytropic. We also consider two different *static* models for the background gas. The table summarizes the five models considered in our first paper. We have since added a new simulation, cc_i1_b1_95p, which uses the orbital parameters of [2].

Model	EOS	Γ	Bkgd	t_{start}	$\langle \dot{M} \rangle^a$ (10^{-8} $M_\odot$ yr^{-1})
cc_i1_b1_95	Isothermal	1	1	1995.5	5.18 ± 2.25
cc_i53_b1_95	Isentropic	5/3	1	1995.5	7.75 ± 6.15
cc_p53_b1_95	Polytropic	5/3	1	1995.5	5.37 ± 4.08
cc_i1_b2_95	Isothermal	1	2	1995.5	4.64 ± 2.19
cc_i1_b1_44	Isothermal	1	1	1944.6	19.0 ± 12.1

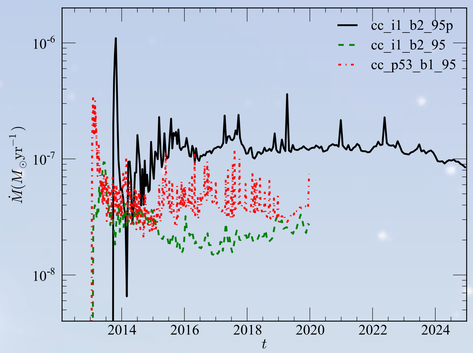
Note. [a] Mass accretion rate, time averaged from when accretion started until t_{stop} = 2020.



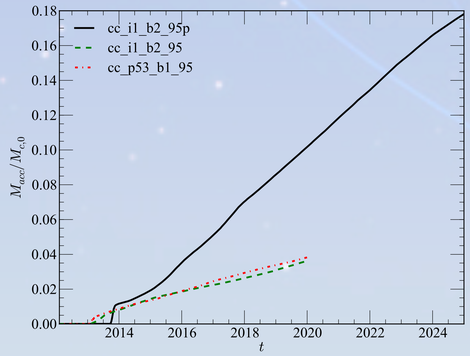
Images showing mesh structure and position at the start of each simulation and again in year 2020. The small, gray sphere near the right-center of the image indicates the effective accretion volume, $r < r_{acc}$ = 750 R_S.



Three-dimensional, volume visualizations of the Br-γ emissivity, $j_{Br\gamma}$, for model cc_i1_b1_95p, spanning the period 2013.6 - 2020. Images are shown from the perspective of an observer on Earth, with axes marked in units of arcsec of RA and Dec offset from Sgr A*.



Plot of the instantaneous mass accretion rate through r_{acc}.

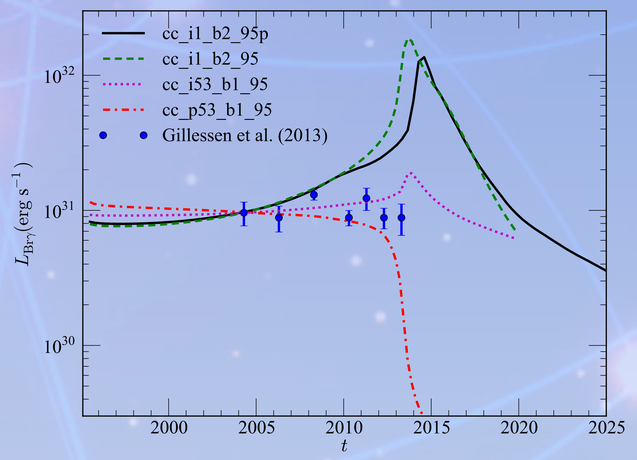


Plot of the total amount of cloud material accreted through r_{acc} as a fraction of the initial cloud mass.

Br-γ Luminosity

For each of our simulations, we calculate Br-γ images and light curves using the case B recombination emissivity from [3]:

$$j_{Br\gamma} = 3.44 \times 10^{-27} \left(\frac{T}{10^4\ \mathrm{K}}\right)^{-1.09} n_p n_e \ \mathrm{erg\ cm^3\ s^{-1}}\ .$$



Br-γ light curves covering the full time span of our simulations.

The light curves (calculated by integrating $j_{Br\gamma}$ over the entire simulation domain) show:

- dramatic brightening starting around 2005 and continuing into 2014 for *all* isothermal models.
- fading of G2 to below the discovery limits sometime in the next decade.

Only models that allow for substantial heating of the cloud appear to match the data reasonably well past 2008.

Acknowledgments

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